Method for adjusting several
parallel connected heat exchangers

5   The invention concerns a method for adjusting several par-
allel connected heat exchanges, which are supplied with a
heat carrying medium.

A heating system with several parallel connected heat ex-
10   changers is known from, for example, DE 100 57 361 A1. The
heat exchangers are partly made as radiators, partly as
heat exchangers for a floor heating system. They are par-
allel connected, that is, they are supplied from the same
source. In the known case, this is a boiler, which feeds
15   an inlet line via a mixing valve.

In a similar manner, the method can also be used for ad-
justing heat exchangers, which are not serving the heating
of a room, but the cooling. While for the heating of a
20   room a fluid is used as heat carrying medium, whose tem-
perature is higher than the temperature of the room to be
heated, for example heated water, a corresponding fluid,
whose temperature is lower, is used for cooling. However,
in principle the problems are the same in both cases.

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In the following, the invention is described in connection
with a heating system. As mentioned, however, it can also
be used for corresponding room cooling. The invention is
particularly suited for use with floor heating systems.

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In floor heating systems the individual heating circuits
provide different flow resistances to the heat carrying
medium. In this connection, a heating circuit comprises a

heat exchanger with its inlets and outlets, however, distinguishing between the heat exchanger and the inlet often being difficult in floor heating systems. The different flow resistances are, for example caused by the fact that one heating circuit must supply a larger room than another and therefore the pipe in the floor is longer. When two such heating circuits with different resistances report a heat demand at the same time, the larger share of the heat carrying medium will flow into the heating circuit with the smallest resistance. This is unfavourable, as the heating circuit then not utilises the total heat of the heat carrying medium, which increases the return temperature from this heating circuit. At the same time, the other heating circuit does not get sufficient heat carrying medium, so that here the heat supply is insufficient.

Desired is, however, a behaviour, which ensures that the heating circuit with the larger resistance receives the major share of the heating fluid, whereas the heating circuit with the smaller flow resistance receives a correspondingly smaller share.

In order to achieve this goal, at present a manual adjustment is made during the installation. In some cases, this adjustment is also called "compensation" or "flow limitation". During this adjustment, the flow resistances of the individual heating circuits, that is, the individual heat exchangers, are changed so that they get a "suitable" hydraulic resistance. When, then, several heating circuits, in the present case two, report the same heat demand, the heating fluid will split up according to the demand.

This method is practised in much case at present. However, it is not always satisfactory. Firstly, each heating circuit needs a throttle, which is accessible from the outside, by means of which the flow resistance can be adjusted. Secondly, a calculation of the setting is required. This is often made in that the flow resistance of the individual heating circuit is calculated. In many cases, such a calculation is not very exact. More exact settings can be made by means of a measuring of the flow resistance or the volume flow through the individual heating circuits. However, this method is relatively expensive. By means of the measured or calculated values, the individual heating circuits must be set.

Additionally, the flow resistance of the individual heating circuits is in many cases only an insufficient criterion for the supply of the individual heating circuits. Also the heat resistance of the floor in a floor heating system or the heat demand of a room can have an influence on the setting. For example, the head demand with a carpeted floor will be different than with a floor tile floor.

A room turning south, which is more frequently exposed to sun radiation, will have a different heat demand than a room on the weather side, for example turning north.

The invention is based on the task of providing an easier setting.

This task is solved in making the following steps:

a. Detecting for each heat exchanger a specific size of the heat demand of the heat exchanger in a predetermined period,

b. comparing the specific sizes of all heat exchangers
5   with each other and

c. changing the setting of the heat exchanger with the specific size displaying the smallest heat demand in a manner, which increases the heat demand.

10   With this method, the heat exchanger having the largest consumption of heat carrying medium is, in a manner of speaking, "punished". In the future, it will receive a smaller share of the heat carrying medium, in that it's setting is changed, meaning that, for example, the flow
15   amount is reduced. Here, there are several possibilities, which will be explained in the following. For example, a specific size can be used, which is formed by a ratio between opening times of a valve controlling the flow amount of a heat carrying medium through the heat exchanger, and
20   the predetermined period, or by a desired value deviation. The correction then occurs in that the ratio of the opening times to the predetermined period in the first case or the desired value deviation in the second case is reduced. Sooner or later, this will ensure that all heat exchangers
25   get the same priority, in that all heat exchangers have the same resistance and thus can demand the same heat amount. This is the object of the control. Thus, also the volume flow through the heat exchangers is maximised, which is a clear advantage, for example in connection with
30   floor heating systems, as thus differences in the surface temperature of the floor can be avoided. The specific size used is, for example as mentioned above, in a first case a ratio between opening times of a valve, which controls the

flow amount of the heat carrying medium through the heat
exchanger and the predetermined period. In other words, a
duty cycleof the valve is used. When, in the predetermined
period of, for example 48 hours, the valve is open for
5   twelve hours, the ratio is 0.25. Usually, a heat exchanger
with a small resistance has a small opening ratio, and a
heat exchanger with a large resistance has a large opening
ratio (of course on condition that the variations of the
heat demand and of the floor design are small). Now, with
10   a heat exchanger, whose valve has a small opening ratio,
the setting can be changed so that the flow amount is re-
duced. In this case, the valve is forced to remain open
longer, to permit the required amount of heat carrying
fluid to pass to the heat exchanger. In a further embodi-
15   ment, a desired value deviation of each heat exchanger can
be determined as specific size and a setting of the heat
exchanger with the smallest desired value deviation can be
made. The heat exchanger having the smallest desired value
deviation is thus "punished", as in the future it will re-
20   ceive less heat carrying medium. In many cases, the de-
sired value deviation is easily determined, as it is
needed for the operation of a controller anyway. In order
to simplify the understanding, the following description
is based on the assumption that with a small heat demand
25   the specific size is large and with a large heat demand
the specific size is small. Depending of the concrete de-
termination of the specific size, the conditions can also
be vice versa.

30   Preferably, the setting of all heat exchangers is changed
in this manner, except for the heat exchangers, whose spe-
cific size displays the largest heat demand. Thus, the de-
sired setting of all heat exchangers can be realised rela-

tively fast. The predetermined period should have a certain duration, for example 48 hours or even seven days. In principle, this period merely serves the purpose of keeping the effects of undesired influences small, as the setting should not be changed during air renewal or sun radiation. The period required for forming a mean value is relatively long. As, however, the setting can be changed for relatively many heat exchangers at the same time, this long period is uncritical, once it has passed. Then, in a manner of speaking, a time window is placed over the system, so that changes, which occur by season, can also become part of the setting of the heat exchangers.

Preferably, the setting of at least one other heat exchanger is changed so that the specific size is increased, that is the heat demand is reduced. When, for example, the flow amount is always only reduced, there is a theoretical possibility that sometime the flow amount has fallen to zero and no heat exchanger is supplied with heat any longer. This case is safely avoided by the increase of the specific size in particular cases.

In a particularly preferred embodiment, it can be endeavoured that an opening period in the range from 50 to 80% of the predetermined period is set for all heat exchangers. For example, it may be ensured that the final result for all heat exchangers, or rather, their valves will be a duty cycleof 0.6. This means that all valves are open for 60% of their predetermined periods. The exact values of course also depend on the inlet temperature of the system, in which the heat exchangers are located.

In a preferred embodiment it is ensured that a common re-
turn temperature for the heat exchangers is determined and
that it is established, at which heat exchanger the return
temperature increases or decreases, when the heat ex-
changer is opened or closed, the setting of a heat ex-
changer being changed by way of a reduction of the spe-
cific size, when the return temperature increases at the
opening of this heat exchanger. In the ideal case all heat
exchangers should have the same return temperature, when
the floor design and the heat demand per area of the heat
exchangers are the same for all heat exchangers. When, now,
it turns out that the return temperature increases, when a
heat exchanger opens, this indicates that in principle
this heat exchanger receives too much heat carrying medium.
It is thus "punished", as the specific size is reduced,
for example in that the flow amount is throttled. When,
however, it is established that the return temperature
drops after opening a heat exchanger, this heat exchanger
must supply too much heat, that is, the heat carrying me-
dium returning from this heat exchanger is too cold. In
the future, it will be supplied with more heat carrying
medium.

Preferably, the setting is changed by a change of an am-
plification in a controller. The controller can, for exam-
ple, be a thermostat element, a motor valve or an electri-
cal p-band adjuster, in which the "punishment" is a change
of the amplification. In many cases, this can easily be
realised.

Alternatively or additionally, a pressure difference over
the heat exchanger can be changed. With the same opening
width of the valve, a larger pressure difference will

cause an increased flow amount. The pressure difference can, for example, be changed in that a throttle wit a larger or smaller flow resistance is arranged at the inlet or at the outlet. Also a pump control can be used to change
5   the pressure difference.

In a further embodiment, it is ensured that the setting is changed in that the maximum opening width of the valve of the heat exchanger is changed. When, for example, the
10 maximum opening width is reduced, the valve is forced to remain open longer. This is particularly advantageous, when the duty cycleof the valve is used as specific size.

Finally, the setting can be changed by changing the open-
15 ing times of the valve. In this case, it is advantageous that during opening periods, which are determined by a heat demand, the valve is periodically closed.

In the following, the invention is described in detail on
20 the basis of preferred embodiments in connection with the drawings, showing:

Fig. 1   a schematic view of a heating system

25 Fig. 2   a schematic view of a control circuit for a heat exchanger

Fig. 3   a schematic view of a controller

30 Fig. 4   several time courses explaining the controller according to Fig. 3

Fig. 5   another embodiment of a controller

Fig. 6   views explaining the mode of functioning of the
           controller according to Fig. 5

5   Fig. 1 shows a heating system 1 for heating several rooms
     2 to 5 in a house. Each room has a floor heating. For this
     purpose, heat exchangers 6 to 9 are shown.

     In the following, the invention is explained on the basis
10   of a heating system with floor heating. However, it is ob-
     vious that the principle of the setting or compensation
     explained in the following can also be used for heating
     systems working with radiators or heating systems, in   -
     which a floor heating is used together with radiators.
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     In a similar manner, the invention can also be used with
     ceiling cooling systems, which do not lead hot water
     through radiators or heat exchangers for heating a room,
     but cold water (or another heat carrying fluid) for cool-
20   ing a corresponding room.

     In the present case, the individual heat exchangers 6 to 9
     are passed by a heating fluid, namely hot water, which is
     distributed to the individual heat exchangers 6 to 9 from
25   an inlet pipe 10 branching off into the individual feeder
     pipes 11 to 14. At the inlet of the inlet pipe 10 is lo-
     cated a mixing valve 15, which can be adjusted by, for ex-
     ample, an electric motor via a regulating unit 16. By
     means of the mixing valve 15, cold water from a return
30   pipe 17, which receives the heating water from the heat
     exchangers 6 to 9, can be added. In this way, it is possi-
     ble to reduce the inlet temperature below a temperature,

which originates from a heating boiler 18 (or another heating source.

The heating fluid amount, which is actually led to each
5   heat exchanger 6 to 9, is determined by valves 19 to 22.
These valves are controlled by a common control device 27.
For this purpose, dotted lines are shown as connections
between the valves 19 to 22 and the control device 27.
These line paths can on the one side be actually available
10   signal lines, for example in the form of electrical lines
or glass fibre lines. However, they can also be made as
wireless paths, when the corresponding information between
the control device 27 and the valves 19 to 22 are trans-
mitted by electromagnetic waves, for example radio waves.
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The control device 27 receives the information about the
temperature in each room 2 to 5 via temperature sensors 23
to 26 located in each room 2 to 5. The related line paths
are shown with dotted lines. Also here, the corresponding
20   line paths can be actual lines. However, the paths can
also be wireless, for example by means of radio waves.

The separation of the valves 19 to 22 from the temperature
sensors 23 to 26 as shown in Fig. 1 does not necessarily
25   have to exist. The valves 19 to 22 and the temperature
sensors 23 to 26, respectively, can be combined in one
component like a radiator thermostat valve. Such an em-
bodiment is particularly expedient, when, a radiator is
used instead of the heat exchangers 6 to 9 for a floor
30   heating. Also when combining valves and temperature sen-
sors in one component, however, there is a connection be-
tween the radiator thermostat valves and the control de-
vice 27.

A sensor 28 is located in the return pipe 17, which re-
turns the heating water from all heat exchangers 6 to 9 to
the mixing valve 15 or to the heating boiler 18, respec-
tively. Also the sensor 28 is connected with the control
device 27. Finally, also an outdoor temperature sensor 30
can be connected with the control device 27.

The heat exchangers 6 to 9 do not all have the same flow
characteristic. A heat exchanger having to heat a larger
room, usually also has a longer flow length and thus a
larger flow resistance than a heat exchanger, which is
provided for a smaller room. Without additional measures,
this causes that, when both heat exchangers report a heat
demand, for example because of a signal of the temperature
sensor 23 to 26, and the valves 19 to 22 are opened, the
largest share of the heating water will flow into the heat
exchanger, which has the smallest flow resistance. This
has several disadvantages. Firstly, it causes an increased
return temperature from this heat exchanger, as the heat-
ing water has not been sufficiently cooled. Secondly, the
heat exchanger with the largest flow resistance is insuf-
ficiently supplied, so that it does not heat the room suf-
ficiently. Desired is, however, a behaviour, in which (in
the present example) the heat exchanger with the largest
flow resistance also receives the largest share of the
heating water.

Additionally, the flow resistance of the heat exchanger is
not necessarily the only criterion. Also the heat resis-
tance of the floor or the heat demand of the room are cri-
teria for the required amount of heating water of the in-
dividual heat exchanger to produce the desired temperature

in the room in the most efficient manner. For example, it makes a difference, if the floor is covered by a carpet or by floor tiles. Also a room turning south will need less heating water than a room turning north.

Usually, a setting adjustable from the outside is used to provide all heat exchangers 6 to 9 with the same priority. This, however, is expensive and can normally not be realised with the required accuracy. Therefore, in the present case a different method is used.

In the period, in which the heat exchangers 6 to 9 "consume" heat, that is, have a demand for heating fluid, which is detected by the temperature sensors 23 to 26, an opening behaviour A is defined. A heat exchanger, which was active for, for example, 12 hours during the latest 48 hours, has the opening ratio A = 12/48 = 0.25. This opening ratio can also be called "mark space ratio".

Usually, a heat exchanger with a small flow resistance has a small opening ratio and a heat exchanger with a large flow resistance has a large opening ratio (assuming in connection with this generalisation that the variations in the heating demand and in the floor design are small).

In order to provide all heat exchangers with the same priority, in other words, to provide them with the same opening ratio, the following method is used:

The average opening ratio for all heat exchangers is measured over a predetermined period of, for example, 48 hours. The opening ratio is defined to be the share of the total period, in which the measured temperature is below the de-

sired value, divided by the predetermined period. Instead
of 48 hours, also other periods can be defined as prede-
termined period, for example a week. The predetermined pe-
riod primarily serves the purpose of avoiding undesired
influences. Thus, the "setting" shall not be changed dur-
ing air renewal or when the sun shines.

Then, the opening ratios A of all heat exchangers 6 to 9
are compared, and the opening ratio is used as a specific
size.

The heat exchanger with the smallest opening ratio A is
"punished". Only the heat exchanger with the largest open-
ing ratio remains unpunished. The "punishment" means that
the flow through the punished heat exchangers is reduced.
This can be made in different manners, for example, in
that a heat exchanger is forced to remain closed, also
when actually it demands heat. Alternatively, the lifting
height of the valves 19 to 22 can be limited, that is, the
heat exchanger receives less heating fluid as usual, mean-
ing that it has to demand heat for a longer period, which
leads to the desired larger opening ratio. After a certain
period, all heat exchangers 6 to 9, or rather their valves
19 to 22, will have the same opening ratio. This opening
ratio can, for example, be in the range from 0.5 to 0.8. A
favourable opening ratio is, for example, 0.6.

Under certain circumstances, it may be favourable to re-
ward the heat exchanger(s) with the largest opening ratio
at the same time as the heat exchanger with the smallest
opening ratio is "punished", that is, to ensure that the
flow amount through this heat exchanger is increased. The
"reward" can also be a less severe "punishment".

Two possibilities of changing the setting of the heat exchangers 6 to 9 are shown in the Figs. 2 to 6.

5   Fig. 2 shows a control circuit as an example for the room 2. The elements here have the same reference numbers as in Fig. 1. The inlet of heating fluid to the heat exchanger 6 is controlled by the valve 19, which then influences the temperature in the room 2. This temperature is determined
10   by the temperature sensor 23 and fed back to an addition point 29, which also receives the desired value via a desired value inlet 31. A further addition point 32 is shown schematically, at which interfering sizes 33, for example, external temperature influences, can be considered. Such
15   interfering sizes can be external temperature influences, which are, for example, caused by increased sun radiation or by an air renewal in the room.

Between the addition point 29 and the valve 19 is located
20   a controller 34, which is explained in the following on the basis of Fig. 3.

Via the control device 27, the controller 34 does not only receive the opening signal S1 for the valve 19, that is,
25   its own control circuit, but also the signal S2...Sn for the remaining control circuits. These signals are shown in Fig. 4a, in which they are drawn over a predetermined period P. For each signal S1...Sn an opening ratio is determined on the basis of the following formula:

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$$Asn = \frac{\sum\limits_{1}^{m} Pn}{P}$$

Pn being the opening periods in the signal Sn and m being the number of opening periods. On the basis of this opening ratio, which can also be called mark space ratio, the demand for heat carrying fluid can be determined. For calculating the mark space ratio, calculation units 35 are provided. Of course, each controller 34 does not have to have its own calculation unit. The calculations can also be made centrally in the control device 27.

In a maximum value generator 36 the largest duty cycleAs-max is determined, and on the basis of this largest opening ratio and the opening ratio of the presently controlled valve a ratio is formed:

$$\frac{Asn}{As - \max}$$

A P-band controller receives this size, and accordingly forms a punishment signal 37 shown in Fig. 4b. This punishment signal is formed as follows: A saw-tooth shaped signal with a period tm and a predetermined rise are currently compared with the opening relation Asn/As-max. As long as the opening ratio is smaller than the saw-tooth signal 38, the punishment signal 39 is on. As soon as the saw-tooth signal 38 exceeds the opening ratio signal 39, the punishment signal 37 is off.

Under the punishment signal 37, the unprocessed control signal 4o for the valve 19 is shown. This control signal 40 is now logically linked with the punishment signal to get the actual control signal 41. The actual control signal 41 is only "on"; when both the unprocessed control signal 40 and the punishment signal 37 are "on". In the

remaining periods, the processed control signal 41 is "off". In this manner, the flow through the heat exchanger 6 can be reduced. It can be seen that with a larger open-ing ratio the curve 39 is displaced upwards, so that the

5   punishment signal 37 "cuts off" less shares from the un-processed control signal 40.

Finally, a simple on/off control is concerned, with which the flow of heating fluid through the heat exchangers 6 to

10   9 can be controlled in dependence of the heat demand of all heat exchangers 6 to 9, which are connected to the same inlet line 10.

Fig. 5 shows a second possibility. Here, the controller 34

15   receives not only the desired value deviation ε1 of its own control circuit, but also the desired value deviations ε2...εn of the other control circuits, which are connected to the same inlet line 10. Via filters 42, these desired value deviations are led to a maximum value generator 36.

20   From the actual desired value deviation εn and the maximum desired value deviation ε-max a quotient is formed, which represents the relative desired value deviation. The rela-tive desired value deviation is led to a punishment factor generator 43, which generates an amplification factor Gpn

25   in dependence on the relative desired value deviation. A corresponding curve course with the punishment factor is shown in Fig. 6b. This punishment factor is then multi-plied by the controller signal shown in Fig.6a, so that the amplification factors at different desired value de-

30   viations shown in Fig. 6c occur. For example, the "punish-ment" may consist in that smaller thermostat valve ampli-fications are made or that a smaller differential pressure

over the individual heat exchangers during the control of string valves.

With the temperature sensor 28 in the return line 17 as
5 shown in Fig. 1, further advantages can be achieved. The temperature in the return line 17 can namely be used as a further criterion for determining, if the supply to the heat exchangers 6 to 9 is optimal.

10 When, for example, a heat exchanger 6 to 9 opens or closes, the common return temperature will change relatively fast. When the specific heat exchanger and its influence on the return temperature are known, differences in the floor design and in the heat demand can be compensated in the fol-
15 lowing manner.

The common return temperature is determined before opening and closing a heat exchanger. The temperature is determined after opening or closing the heat exchanger. When
20 the temperature increases at each opening of the heat exchanger and decreases at each closing, the heat exchanger is punished, that is, the flow amount is throttled. In the opposite case, the heat exchanger is rewarded, that is, it receives more heat carrying fluid.
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Such a control is particularly advantageous, when the desired value deviation is known. When this is not considered, other measures must be taken to prevent that the heat exchanger can be so "severely" punished that it can-
30 not supply the required heat at a given inlet temperature.

The compensation or setting can also be combined with an inlet temperature control as described in DE 100 57 361 A1.

This causes that further to a similar heat demand from all heat exchangers 6 to 9 also the same heat demand is achieved throughout the heating season independently of the load.

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